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Student Energy Research Spotlight: Design and Modeling of Hybrid Photovoltaic Systems in Arctic Environments

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Design and Modeling of Hybrid Photovoltaic Systems in Arctic Environments

By Capt Ruth Fish, USMC

Energy Security is a key concern for military installations. A stand-alone hybrid microgrid provides energy security for remote naval facilities due to the sustainability, flexibility, and redundancy of the PV arrays, batteries, and generator, respectively.

This thesis develops a methodology to size the energy resources of a military hybrid microgrid and implements this methodology in a user-friendly tool that is easily accessible to engineers and energy managers at military facilities, especially those in remote locations and extreme climates such as the Artic. The tool focuses on increasing the resilience of specifically military microgrids and on accurately sizing distributed energy resources (DERs) to account for climate. While complying with IEEE standard 1562, the tool allows the user to specify environmental factors of the location and decide upon the total dependence of the system on solar power.

Three experiments with a commercial off-the-shelf (COTS) microgrid validated the design tool and physics-based model. Then, two case studies were conducted to understand the parameters for the design of hybrid microgrids for military installations in a range of climates. In the first case study, the annual performance of 30 differently sized DERs was compared, based on fuel consumption, size, and mission availability. Fuel consumption was plotted versus the solar fraction, which is a number between 0 and 1 to indicate how much of the load power is provided by PV arrays. In the second case study, the daily performance of the same 30 DERs was compared based on their ability to sustain their load with an inoperable generator.

The research revealed the relationship between solar fraction and fuel consumption in various climates as well as considerations for microgrid design in environments with great variability in the amount of available sunlight throughout the year.

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